The Effect of Nitrogen Applications Split Between Autumn and Spring on Amenity-types of *Lolium perenne* L. Grown for Seed.

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ABSTRACT

Three amenity-type perennial ryegrass (*Lolium perenne* L.) cultivars, Elka, Taya and Pippin were undersown in 1991, 1992 and 1993 in spring barley at two locations, Roskilde and Rønhave. The objective was to assess the effect on seed yield and yield components of nitrogen (N) application split between autumn and spring. Nitrogen application rates were 0, 30 or 60 kg N ha^{-1} in autumn combined with 70, 100 or 130 kg N ha^{-1} in spring. Seed yield did not differ among cultivars or locations but was significantly increased by autumn N, spring N and their interaction. On average over the three years both 30 and 60 kg N ha^{-1} in autumn increased seed yield, but this increase was lower than that for a single spring application, provided that the N applied in spring was 100 kg ha^{-1} or greater. N content in above ground plant material varied considerably among years but not cultivars. Correlation analysis of N content, yield components and seed yield revealed that when autumn N application resulted in an increasing N content in above-ground plant material, fertile tiller number and seed weight increased. However, these two components were negatively correlated, and total seed yield was therefore not affected on average over the three years. The one exception was in 1991 when at one location dry matter production in autumn was low, and autumn N application resulted in increased N content, fertile tiller number and seed yield.

Additional index words: Lolium perenne L., nitrogen, split application, seed yield, seed yield components.

INTRODUCTION

An increased production of fertile tillers after autumn nitrogen (N) application has been reported in a number of grass species (Nordestgaard, 1986). This increase in fertile tiller number is often associated with a higher total seed yield. From Danish field investigations, autumn N application is recommended in smooth stalked meadow grass (*Poa pratensis* L.), red fescue (*Festuca rubra* L.), cocksfoot (*Dactylis glomerata* L.) and meadow fescue (*Festuca pratensis* Huds.) (Nordestgaard, 1971; 1972; 1974; 1989; 1990; Nordestgaard and Larsen, 1971). In timothy (*Phleum pratense* L.) and perennial ryegrass (*Lolium perenne* L.) autumn N application has also lead to an increase in fertile tiller number (Nordestgaard, 1977; 1983), but not seed yield. In contrast, in Italian ryegrass (*Lolium multiflorum* Lam.), both fertile tiller production and total seed yield were unaffected by autumn N applications (Nordestgaard, 1985). These inconsistent results may be associated with variation in the ability of the individual grass species to initiate and develop reproductive tillers. This theory is supported by the fact that Italian ryegrass, perennial ryegrass and timothy, in contrast to smooth stalked meadow grass and red fescue, have no or moderate requirement for primary induction (Cooper and Calder, 1964; Aamlid, Heide and Boelt, 1988; Heide,1990). The inconsistent effects of autumn N application may also be explained by different establishment methods as proposed for smooth stalked meadow grass by Larsen and Nordestgaard (1969). In agreement with this, Boelt (1997) concluded that the response to autumn N depended on cover crop species. When red fescue was undersown in winter rape or field pea, autumn N did not increase seed yield. In contrast, application of 30 kg N ha^{-1} greatly enhanced seed yield after winter wheat. The differing response to N application resulting from changing cover crop species might be explained by varying autumn plant density in the undersown grasses or by varying soil N content after cover crop harvest.

The standard growing technique for perennial ryegrass comprises a single application of 100-120 kg N ha^{-1} at the onset of spring growth (Nordestgaard, 1977), which in Denmark is approximately 1 April. This is in agreement with results from N experiments in the Netherlands (Meijer and Vreeke, 1988; Borm, 1993) and in New Zealand (Hampton, 1987). However, if establishment is poor, supplemental N application in autumn is recommended (Nordestgaard, 1977). Hence, the requirement for autumn N in perennial ryegrass appears to vary according to the success of establishment (autumn plant density).

Seed production of perennial ryegrass amenity-types is increasing in Denmark. These types are often slow establishing, and therefore may benefit from autumn N application. Consequently, the studies reported here were initiated in an attempt to assess the effect of autumn N on seed yield and yield components in amenity-type perennial ryegrass cultivars.

MATERIALS AND METHODS

Field experiments were conducted at the Danish Institute of Agricultural Sciences at two locations - Roskilde (55°39'N and 12°05'E) and Rønhave (54°57'N and 9°47'E) on a sandy loam soil and a clay soil, respectively. The perennial ryegrass amenity-type cultivars Elka, Taya and Pippin were spring sown at 200 viable seeds m^{-2} in spring barley cv. Alexis (sown at 120 kg ha^{-1}) in 1991, 1992 and 1993. The dates for sowing and harvesting of cover crops and the dates for sowing, swathing and combine harvesting of the grass seed crops are shown in Table 1. In all years the previous crop was spring barley. Gislum and Boelt (1998) have described the procedures used for crop establishment, crop management, sampling techniques and seed harvest.

Autumn nitrogen (N) was applied at three levels (0, 30 and

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Table 1. Sowing and harvest date for spring barley and sowing, swathing and combine harvest date for the three undersown perennial ryegrass cultivars.

	Established 1991		Established 1992		Established 1993	
	Roskilde	Rønhave	Roskilde	Rønhave	Roskilde	Rønhave
Sowing dates:						
Spring barley	12 Apr 1991	12 Apr 1991	8 Apr 1992	9 Apr 1992	30 Mar 1993	2 Apr 1993
Perennial ryegrass	15 Apr 1991	12 Apr 1991	9 Apr 1992	9 Apr 1992	1 Apr 1993	2 Apr 1993
Nitrogen application dates						
Autumn	1 Oct 1991	23 Sep 1991	22 Sep 1992	22 Sep 1992	28 Sept 1993	27 Sept 1993
Spring	26 Mar 1992	26 Mar 1992	24 Mar 1993	29 Mar 1993	28 Mar 1994	28 Mar 1994
Harvest:						
Spring barley	21 Aug 1991	14 Aug 1992	29 Jul 1992	6 Aug 1992	18 Aug 1993	18 Aug 1993
Seed harvest						
Seed swathed	10 Jul 1992	8 Jul 1992	29 Jul 1993	19 Jul 1993	1 Aug 1994	26 July 1994
Seed combined	17 Jul 1992	17 Jul 1992	5 Aug 1993	2 Aug 1993	7 Aug 1994	3 Aug 1994

60 kg N ha^{-1}) which were combined with three levels in spring (70, 100 and 130 kg N ha^{-1}) in all possible combinations. N was applied as calcium ammonium nitrate. On average at the two locations over the three years of the trial, autumn N was applied on September 26 and spring N on March 26. Immediately before N application in autumn, grass regrowth was cut leaving stubble approximately 10 cm high (if the re-growth had exceeded 15-20 cm). Late November plant samples were cut at one location (Roskilde), within a frame of 0.25 m^2 per plot. Cutting commenced after the first night of frost, which was November 18 on average over the three years. To avoid soil in the plant sample, stubble height was set at approximately 1 cm. After drying plant samples at 80°C, dry matter was recorded and N content determined using the Kjeldahl Method (AOAC, 1990).

The experimental design was a randomised complete block with two replications for both locations. The net plot size was 8m x 2.5m. All results presented are means of three years. Data were analysed as a three-factorial block design regarding year as a random factor. Tests of the main effects of location, cultivar, autumn applied nitrogen, spring applied nitrogen and their interactions were performed by F-tests. To predict the effects of each treatment in the present trial in any future year, the denominator in the F-test was the interaction between the effect in question and year. Means of main effects were separated by least significant difference (LSD) and were declared different at the $P \leq 0.05$ level. Statistical analyses were performed using PROC GLM module and PROC CORR within the Statistical Analysis System (SAS; 1989a, 1989b). Gislum and Boelt (1998) have presented meteorological data for the period 1991-93 included in this study.

RESULTS

Seed yield

Since no variation among years, cultivars and locations was found for the effect of autumn/spring N, mean data are presented. The main effects of autumn N and spring N on seed yield were significant as well as the interaction between them. Autumn application of 30 and 60 kg N ha^{-1} significantly increased seed yield when averaged across the three spring N rates (Table 2) while application of 100 and 130 kg N ha^{-1} in spring increased seed yield irrespective of autumn N. Spring N interacted with autumn N and for all combinations the effect of autumn N was eliminated by

Table 2. Effect of autumn and spring nitrogen application on perennial ryegrass seed yield[1].

Autumn N application rate (kg N ha^{-1})	Spring N application rate (kg N ha^{-1})			
	70	100	130	mean
0	1191	1321	1381	1298
30	1265	1334	1395	1332
60	1321	1386	1378	1362
mean	1259	1347	1385	
$LSD_{autumn\ N}$ $P<0.05$	33			
$LSD_{spring\ N}$ $P<0.05$	63			
$LSD_{spring\ N \times autumn\ N}$ $P<0.05$	187			

[1] *Data are means for three years, three cultivars and two locations.*

Table 3. N content (kg N ha^{-1}) in perennial ryegrass above-ground plant material in autumn for the three experimental years.

Autumn N application rate (kg N ha^{-1})	1991	1992	1993
0	14.9	43.9	27.4
30	24.0	59.3	43.8
60	31.3	75.7	53.4
LSD P<0.05	3.2	6.5	5.5

[1] *Data are means of three cultivars.*

Table 4. Perennial ryegrass dry matter production, N concentration and N content following autumn N application[1]

Autumn N application rate (kg N ha^{-1})	Dry matter (t ha^{-1})	N concentration (%)	N content (kg N ha^{-1})
0	1.501	1.97	28.7
30	1.782	2.42	42.4
60	1.952	2.77	53.5
LSD P<0.05	0.141	0.15	9.2

[1] *Data are means of three years and three cultivars.*

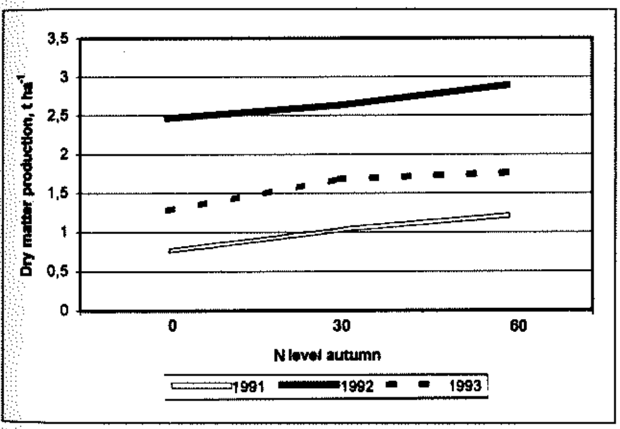

Figure 1. The effect of autumn N level on dry matter production in autumn 1991, 1992 and 1993.

spring N within the same total N amount. The seed yield from plots receiving 0/70 kg N ha^{-1} was significantly lower than from plots receiving 0/130 kg N ha^{-1} and plots receiving more than a total of 130 kg N ha^{-1}.

Fertile tillers

In general fertile tiller number and seed weight were not influenced significantly by the different N combinations. However, the main effect of autumn N on fertile tiller number at Roskilde was significant in 1992, with fertile tillers increasing from 2874 to 3150 and 3436 m^{-2} after application of 0, 30 and 60 kg N ha^{-1} respectively. While mean tiller numbers were higher in 1993 and 1994 with an average of 3547 and 3372 m^{-2} respectively, this was not due to autumn N. In 1992 seed weight decreased with increasing N rates whereas it increased in 1994.

Dry matter production in autumn

Results for dry matter production from plant samples taken in late November varied with experimental year and N rate. This is in contrast to the minor effect of autumn N rate on seed yield and yield components. Highest dry matter production was obtained in 1992 with 2.662 t ha^{-1} on average for the three autumn N rates. Dry matter production was significantly lower in 1993 and 1991 (1.571 and 1.002 t ha^{-1} respectively). Figure 1 shows the effect of autumn N application rate on dry matter production for each of the three experimental years. Dry matter production did not vary among cultivars.

N content in above-ground plant material in autumn

Like dry matter production, the N content in above-ground plant material varied considerably among experimental years and N rate (Table 3). In 1991, N content was low. Plots receiving 60 kg N ha^{-1} in 1991 had a lower N content (31.3 kg N ha^{-1}) than plots which were not fertilised in 1992 (43.9 kg N ha^{-1}). N content did not vary among cultivars.

On average over the three experimental years, N application rate in autumn increased dry matter production, N concentration and N content (Table 4). N concentration was 2.31, 2.24 and 2.61% in 1991, 1992 and 1993 respectively on average for application rate and cultivar. In 1991 and 1992, N concentration did not vary among cultivars, but in 1993 cv. Pippin had a lower N concentration than cv. Elka and Taya (data not presented).

N content and seed yield components

N application stimulated dry matter production and N content in above-ground plant material. Dry matter production and N content were significantly correlated (r^2=0.916; Table 5). Increasing N application also increased N concentration, which was significantly correlated with N content (r^2=0.344). Increased dry matter production and N content resulted in a higher number of fertile tillers and a higher seed weight. Since N content in above-ground plant material was affected both by application rate and year, the effect of increasing N content due to increasing N rate was calculated. When N content in above-ground plant material was increased by 1 kg ha^{-1} by increasing the N

Table 5. Correlation coefficients between dry matter production, N concentration and N content in above-ground plant material in late autumn, and seed yield and its components[1]

	Dry matter production	N concentration	N content	Seed yield	Fertile tillers	Seed weight
Dry matter production	1.000	-0.030	0.916*	-0.024	0.189*	0.342*
N concentration		1.000	0.344*	0.183*	0.083	0.153
N content			1.000	0.041	0.184*	0.369*
Seed yield				1.000	-0.398*	0.589*
Fertile tillers					1.000	-0.308*
Seed weight						1.000

*P≤0.05

[1] *Data are means of three years and three cultivars.*

application rate, fertile tiller number was increased by 10 tillers m^{-2} on average over the three years. However, in 1991 where dry matter production and N content were low, each increase in N content by 1 kg N ha^{-1} resulted in an increase in fertile tiller number in 1992 of 34 tillers m^{-2}. In 1992 and 1993 where dry matter production and N content were higher, no significant effect was observed for fertile tiller number.

Similarly a positive effect of N content was found on seed weight. However, since fertile tiller number and seed weight were negatively correlated, an increase in N content did not lead to an increase in seed yield on average over the three years. Analysing data from the individual years showed that when fertile tiller number increased due to an increased autumn N application rate, total seed yield was increased in 1992 only. In 1993 and 1994 the correlation between tiller number and seed yield was not significant.

DISCUSSION

Amenity-types of perennial ryegrass were insensitive to autumn N when the spring application rate was 100 kg N ha^{-1} or more. These results support the conclusions reported from New Zealand by Hampton (1987) and from the Netherlands by Meijer and Vreeke (1988) and Borm (1993). Generally autumn N is considered to increase fertile tiller production (Nordestgaard, 1986), but under the conditions and application rates in this trial autumn N had no effect on tiller number for all but one site in one of the three experimental years. However, it should be noted that fertile tiller numbers were relatively high, averaging 3153-3547 m^{-2} over the three years. Hampton and Fairey (1997) suggested that fertile tiller number for seed production in amenity-type perennial ryegrass should lie between 2000-3500 m^{-2}. Accordingly, it can be concluded that establishment of all the perennial ryegrass crops was successful, and that fertile tiller number was not a limiting factor for seed yield in this study.

N content of above-ground plant material in late autumn varied between 14.9 and 75.7 kg N ha^{-1} according to N application rate and year, although experimental year rather than N rate explained most of this variation. Therefore, the effects of N application rate on dry matter production, N content, seed yield and yield components were analysed for each experimental year independently. While a significant and positive correlation between autumn N content and fertile tiller number was found on average over the experimental years whereby an increase in N content of 1 kg N ha^{-1} increased fertile tiller number by 10 tillers m^{-2}, in 1991, an increase in autumn N content of 1 kg N ha^{-1} increased fertile tiller number in spring 1992 at Roskilde by 34 tillers m^{-2}. Fertile tiller number at Roskilde was low in 1992 and increased from 2874 to 3150 and 3436 m^{-2} after application of 30 and 60 kg N ha^{-1}. Hence it is suggested that in years where autumn dry matter production is low, implying a seed yield limitation because of low fertile tiller numbers, splitting the total N amount between an autumn and spring application should increase fertile tiller number and consequently seed yield. This is consistent with other Danish trials on agricultural types of perennial ryegrass (Nordestgaard, 1977). Meijer and Vreeke (1988) also reported that late sown crops and crops grown under dense cover crops benefited from autumn N, while Hill (1972) reported increased production of fertile tillers and a higher seed yield when nitrogen was split between autumn and spring.

Despite there being a low N content in the above-ground plant material in autumn 1991, there was a pronounced effect of autumn N on subsequent fertile tiller production. Irrespective of autumn N application rate, dry matter production was very low in 1991. This would logically be explained by either poor establishment of the undersown perennial ryegrass or by poor autumn growth conditions but establishment was good and meteorological data (Gislum and Boelt, 1998) do not explain this result. It is therefore concluded that indicators for crop growth/crop development are required in order to be better able to optimise N application between autumn and spring. Results from the present study showed that nitrogen concentration was not correlated with dry matter production. Therefore N concentration is not expected to be a good indicator for autumn N demand in perennial ryegrass crops grown for seed production.

Based on the results of this study, it is recommended that for amenity types of perennial ryegrass spring application of a total of 100-130 kg N ha^{-1} is optimal. However, in years where establishment of the undersown grasses is poor, or autumn dry matter production is low, a split application between autumn and spring will increase fertile tiller number and consequently seed yield.

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